
[CERTIFIED TRANSLATION FROM GERMAN]

- 1 -

5

10 **Title**
Method and Arrangement for Spatial Display

Field of the Invention

15 The invention relates to arrangements for spatial display, and in particular to such arrangements that present an image visible in three dimensions to one or several observers without the use of auxiliary aids such as glasses.

20 **Description of Prior Art**

Various methods and arrangements of the kind are known in prior art.

Many of the known methods and arrangements for spatial display are based on the spatial or spatial-temporal splitting of different views of a scene on an image display device. The said views are, as a rule, either images taken of different stratigraphic depth planes or from different perspectives. The image display devices are, e.g., LC displays, which are in increasingly widespread use. US 5 936 774, for instance, describes a method and an arrangement for the autostereoscopic presentation of two to four perspective views on an LC display. Arrangements autostereoscopic presentation based on LC displays are also described in EP 0 791 847, EP 0 783 825, and JP 8 194 190. An advantageous arrangement of this kind is described in DE 100 03 326 C2; it uses at least one wavelength filter array, which assigns propagation directions to light coming from different pixels. The said picture elements visualize bits of partial image information from different views of a scene or object. Due to the light propagation directions assigned, the left and right eyes of an observer

25
30
35

- 1 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 2 -

predominantly see respectively a first and second selection of views, so that the observer gets a spatial impression.

Although these methods and arrangements have several advantages, such as the
5 potential reduction of moiré effects, suitability for a group of observers, and the possibility to do without auxiliary aids to spatial vision, they are characterized on the downside by an impaired brightness.

10 **Description of the Invention**

The problem of the invention is to improve arrangements of the kind described above in such a way as to achieve an increased brightness in 3D display. Another purpose is to achieve, in special embodiments of the arrangements according to the invention, an improved readability of normal text.

15

This problem is solved by an arrangement of the kind described before, for the spatial display of a scene or object, comprising an imaging device with a great number of picture elements (pixels) α_{ij} in a raster of rows j and columns i , in which the pixels α_{ij} render bits of partial information from at least three views A_k ($k=1 \dots n$, $n \geq 3$) of the scene or object, and further comprising one or several arrays of many wave-
20 length and/or gray-level filters arranged in rows q and columns p and designed as filter elements β_{pq} , part of which are transparent to light of specified wavelength ranges, whereas the remaining part are opaque to light, these arrays being arranged (in viewing direction) in front of and/or behind the imaging device with the pixels
25 α_{ij} , so that propagation directions are given for the light emitted by the pixels α_{ij} , and in which each pixel α_{ij} corresponds with several filter elements assigned to it, or each filter element corresponds with several pixels α_{ij} assigned to it, in such a way that each straight line connecting the area center of a visible segment of the pixel α_{ij} and the area center of a visible segment of the filter element corresponds to a
30 propagation direction, and in which, within a viewing space in which the observer(s) is (are) located, the propagation directions intersect in a great number of intersection points, each of which represents an observer's position, so that an observer at any of these positions will predominantly see bits of partial information from a first selection of views with one eye, and predominantly bits of partial information from
35 a second selection of views A_k ($k=1 \dots n$); the said problem being solved in that, in at least a segment of at least one of the arrays, the ratio between the areas covered by

[CERTIFIED TRANSLATION FROM GERMAN]

- 3 -

filter elements β_{pq} transparent to light of specified wavelength ranges and the total area of all filter elements β_{pq} , multiplied by the average number n' of the different views displayed per row j of the raster of pixels α_{ij} , is greater than 1.

- 5 The brightness can be increased by allowing more light to reach the observer via the filter elements.

10 In a preferred version that is easy to manufacture, the filter elements transparent to light of specified wavelength ranges are designed as filters that are essentially transparent to light of the entire visible spectrum. Although the filter elements are mostly designed as directly selective wavelength filters, the arrangements according to the invention also work with any other kind of filters, such as, for example, polarizing filters or holographic optical elements.

15 Unlike in conventional arrangements, the 3D impression remains without noticeable impairments in such arrangements in which the transparent filters are so dimensioned that always more than one pixel α_{ij} is visible per visible raster segment relative to the pixel area. This is the case especially with such preferred embodiments of the invention in which the quotient of the sum of areas of the filter elements β_{pq} that are largely transparent to light of essentially the entire visible spectrum and the sum of areas of all filter elements β_{pq} of the respective array has a value that is between the quotient $Q1=1.1/n'$ and the quotient $Q2=1.8/n'$, so that, due to the filter elements β_{pq} transmissive to light of the entire visible spectrum, always about 1.1 to 1.8 pixels α_{ij} are visible, on average, per visible segment of the raster relative to the pixel area. Experiments have shown, however, that this is also the case with quotients greater than 1.8, such as, for example, 2.0.

30 In another embodiment of the invention, the segment, in case of parallel projection onto the raster of pixels α_{ij} , comprises at least one row j or at least one column i . A preferred embodiment, in which the 3D impression is not noticeably impaired either, is given if, in case of parallel projection of a sufficiently large filter segment of at least one array of filter elements β_{pq} onto at least one row j or at least one column i of the raster, at least $1.1/n'$ times and maximally $1.8/n'$ times the area of the respective row j or column i are covered by filter elements β_{pq} that are essentially transparent to light of the entire visible spectrum, so that, because of these filter elements β_{pq} transparent to light of the entire visible spectrum, always about 1.1 to

[CERTIFIED TRANSLATION FROM GERMAN]

- 4 -

1.8 pixels α_{ij} are visible, on average, per visible segment of the raster relative to the pixel area.

In another preferred embodiment of the invention, the array is provided with at least one first continuous belt of transparent filters extending from one edge of the array to the opposite edge, and at least one second continuous belt of transparent filters extending from one edge of the array to the opposite edge, with the major extensions of these two belts on the array not being aligned in parallel with each other.

Major extension, in this context, means the line connecting two transparent filters of one and the same belt, located at opposite ends of the belts. In case that several transparent filters are located at one end of the belt, the term refers to the area centroid of the total area of these transparent filters.

Preferably, at least one of the continuous belts of transparent filters is parallel with the upper, lower, left or right edge of the respective array of filter elements β_{pq} and/or parallel to the upper, lower, left or right edge of the raster of pixels α_{ij} .

It is of advantage if many such continuous belts of transparent filters are provided.

It should be noted here that the arrangements according to the invention may, under certain circumstances, work with only two views A_k presented; such circumstances are given if the above-mentioned quotient is close to the lower limit, at approximately $1.1/n'$.

In another embodiment, at least some of the continuous belts of transparent filters are randomly distributed over the array, provided that the said belts are aligned in parallel with each other. As an alternative it is also possible that at least some of the continuous belts of transparent filters are arranged on the array at periodic distances from each other, provided that the said belts are aligned in parallel with each other, wherein preferably every m^{th} row q (with $m > 1$) or every m^{th} column p (with $m > 1$) of the respective array forms such a continuous belt of transparent filters.

In a special embodiment it is provided that, in case of parallel projection of one – but not necessarily each – continuous belt of transparent filters onto the raster of

- 4 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 5 -

pixels α_{ij} (in viewing direction), the pixels α_{ij} that are at least partially covered by transparent filters are predominantly such that render, for a predominant part or exclusively, bits of partial information from one and the same view A_k . However, it is also possible that several of the pixels α_{ij} that are at least partially covered by transparent filters are such that render bits of partial information from at least two different views A_k .

For all arrangements according to the invention, the assignment of bits of partial information from the views A_k ($k=1\dots n$) to pixels α_{ij} of position i,j is preferably performed according to the equation

$$k = i - c_{ij} \cdot j - n \cdot \text{IntegerPart} \left[\frac{i - c_{ij} \cdot j - 1}{n} \right],$$

in which i denotes the index of a pixel α_{ij} in a row of the raster, j the index of a pixel α_{ij} in a column of the raster, and k the consecutive number of the view A_k ($k=1\dots n$) from which the partial information to be rendered on a particular pixel α_{ij} originates. n is the total number of views A_k ($k=1\dots n$) used, and c_{ij} is a selectable coefficient matrix for combining or mixing on the raster the various bits of partial information originating from the views A_k ($k=1\dots n$). The function IntegerPart delivers the greatest integral number that does not exceed the argument put in brackets in the equation.

Further, the filter elements β_{pq} of the filter arrays intended are combined into a mask image depending on their transmission wavelength / their transmission wavelength range / their transmittance λ_b , according to the equation

$$b = p - d_{pq} \cdot q - n_m \cdot \text{IntegerPart} \left[\frac{p - d_{pq} \cdot q - 1}{n_m} \right],$$

in which p denotes the index of a filter element β_{pq} in a row of the respective array and q the index of a filter element β_{pq} in a column of the respective array. b is an integral number that defines one of the intended transmission wavelengths / transmission wavelength ranges or transmittances λ_b for a filter element β_{pq} in the position (p,q) and may adopt values between 1 and b_{\max} , b_{\max} being a natural number greater than 1. n_m is an integral value greater than zero that preferably is the total number k of the views A_k displayed in the combination picture, and d_{pq} is a select-

[CERTIFIED TRANSLATION FROM GERMAN]

- 6 -

able mask coefficient matrix for varying the generation of a mask picture. The function IntegerPart has been defined above.

For the example embodiments described below, corresponding mask coefficient
 5 matrices d_{pq} or coefficient matrices c_{ij} could be given. This is omitted, however, for the sake of brevity.

Preferably, exactly one array of filter elements β_{pq} is provided, and the distance z
 10 between the said array and the raster of pixels α_{ij} , measured normal to the raster, is defined according to the following equation:

$$\frac{p_d}{s_p} = \frac{d_a \pm z}{z},$$

wherein s_p denotes the mean horizontal distance between two neighboring pixels α_{ij} .
 If the filter array, in viewing direction or in a direction normal to the raster, is lo-
 cated before the raster of pixels α_{ij} , z is subtracted from d_a ; if the filter array is lo-
 15 cated behind it, z is added to d_a . p_d is the mean interpupillary distance of an ob-
 server, and d_a is a selectable viewing distance.

Typical distances z are approximately within a range from 1 mm to 25 mm; other
 distances, especially greater ones, are feasible just as well, though.

20 In an advantageous embodiment, all filter elements provided on the filter array or
 filter arrays are of equal size. In this connection, the area of a filter or a filter ele-
 ment may be between several thousand square micrometers and several square
 millimeters, as a rule. The filter elements or filters β_{pq} have polygonal, preferably
 25 rectangular outlines. The outlines may just as well include curved lines, though.

Other shapes are also feasible for the pixels α_{ij} , such as, for example, polygonal
 shapes, or a herringbone pattern of stripes as in a so-called dual-domain display.
 This implies that the number of filter elements β_{pq} provided on a filter array may
 30 deviate greatly from the number of pixels α_{ij} .

In case no random arrangement of transparent filter belts is provided, the filter
 elements β_{pq} provided on the filter array or filter arrays preferably have an essen-
 tially periodic arrangement.

- 6 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 7 -

In another advantageous embodiment, the light propagation directions for the bits of partial information rendered on the pixels α_{ij} are specified depending on their wavelength / their wavelength range.

5

In another embodiment, on at least one of the arrays of filter elements in at least one row q of the array, immediately adjacent transparent filters border on a different number of immediately adjacent transparent filters in row $q-1$ than in row $q+1$. In this way, the transitions between views during a movement of the observer are influenced.

10

Preferably, each of the filter arrays provided is static and invariable in time, and essentially arranged in a fixed position relative to the raster of pixels α_{ij} , i.e. the imaging device.

15

In another, more special embodiment of the above-mentioned arrangements according to the invention, at least one pixel α_{ij} renders image information that is a mix of bits of partial information from at least two different views A_k , such as, for example, by means of any of the methods described in WO 03/024112 by the present applicant.

20

In the arrangements according to the invention as described above, the imaging device may be, for example, an LC display, a plasma display, or an OLED screen. This is not to exclude that the imaging device may also be a device of any other kind.

25

In special applications it may be desirable, in addition, that the arrangement can be switched between a 2D and a 3D mode, either totally or partially – capability for which each of the arrangements described so far is eligible. For this purpose, a translucent image display device such as, for example, an LC display, and exactly one array of filter elements are provided, the latter being arranged (in viewing direction) between the image display device and a planar illumination device. Also provided is a switchable diffusing plate arranged between the image display device and the filter array, so that in a first mode of operation, in which the switchable diffusing plate is switched to be transparent, a spatial impression is created for the observer(s), whereas in a second mode of operation, in which the switchable diffusing

30

35

- 7 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 8 -

plate is switched to be at least partially diffusing, the action of the array of filter elements is cancelled out to the greatest possible extent, so that the scattered light provides for a largely homogeneous illumination of the image display device and two-dimensional image contents can be displayed on it with full resolution. Accordingly, in the said second mode, no light propagation directions are defined for those partial areas in which the diffusing plate is switched to be diffusing, so that both eyes of the observer essentially see the same image information. Advantageously, the respective 2D positions on the imaging device are made to render two-dimensional image information only rather than an image that is composed of several views.

For switching between 2D and 3D, moreover, at least one array of filter elements may be provided whose pixels, or at least part of them, act as wavelength or gray level filters and which are of an electrochromic or photochromic design, the said array exhibiting, in a first (3D) mode of operation, a filter array structure suitable for three-dimensional display, using especially the pixels of electrochromic or photochromic design, whereas in a second mode of operation the pixels of electrochromic or photochromic design are switched to be as transparent as possible, preferably more or less completely transparent to the entire visible spectrum.

The array may be provided with both wavelength or gray level filters of electrochromic or photochromic design and such having invariable transmission properties, the invariable filters being preferably designed to be essentially completely transparent to the entire visible spectrum.

25

Brief Description of the Drawings

Below, the invention is described in detail with reference to drawings, in which:

Fig. 1 a	shows a filter array in a first embodiment of the invention,
30 Fig. 1 b	schematically illustrates the composition of transparent filter segments from several transparent filter elements,
Fig. 1 c	is a schematic illustration of the embodiment of arrangements according to the invention,
Fig. 2	shows a possible image combination for creating a spatial impression in conjunction with a filter array of the first embodiment,
35	

- 8 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 9 -

- Fig. 3 and Fig. 4 shows examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 1a and Fig. 2,
- Fig. 5 shows another example of the image combination,
- 5 Fig. 6 shows a filter array that is excellently suitable for spatial display in conjunction with the image combination rule illustrated in Fig. 5,
- Fig. 7 and Fig. 8 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 5 and Fig. 6,
- 10 Fig. 9 shows yet another example of the image combination,
- Fig. 10 shows a filter array that is excellently suitable for spatial display in conjunction with the image combination rule illustrated in Fig. 9,
- 15 Fig. 11 and Fig. 12 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 9 and Fig. 10,
- Fig. 13a shows a filter array in another embodiment of the invention, preferably to be applied with an image combination rule as illustrated in Fig. 9,
- 20 Fig. 13b schematically illustrates the composition of transparent filter segments from several transparent filter elements, equivalent to the filter array shown in Fig. 13a,
- Fig. 14 shows an example of pixels or partial areas of pixels possibly visible to one eye of the observer, based on the conditions shown in Fig. 9 and Fig. 13a,
- 25 Fig. 15 shows a filter array in another embodiment of the invention, preferably to be applied with an image combination rule as illustrated in Fig. 9,
- 30 Fig. 16 shows an example of pixels or partial areas of pixels possibly visible to one eye of the observer, based on the conditions shown in Fig. 9 and Fig. 15,
- Fig. 17 shows a filter array in another embodiment of the invention, preferably to be applied with an image combination rule as illustrated in Fig. 9,
- 35

[CERTIFIED TRANSLATION FROM GERMAN]

- 10 -

- Fig. 18 shows an example of pixels or partial areas of pixels possibly visible to one eye of the observer, based on the conditions shown in Fig. 9 and Fig. 17,
- Fig. 19 shows another example of the image combination,
- 5 Fig. 20 shows a filter array that is excellently suitable for spatial display in conjunction with the image combination rule illustrated in Fig. 19,
- Fig. 21 and Fig. 22 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 19 and Fig. 20,
- 10 Fig. 23 shows another example of the image combination,
- Fig. 24 shows a filter array that is excellently suitable for spatial display in conjunction with the image combination rule illustrated in Fig. 23,
- 15 Fig. 25 and Fig. 26 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 23 and Fig. 24,
- Fig. 27 shows another example of the image combination,
- Fig. 28 shows a filter array that is excellently suitable for spatial display in conjunction with the image combination rule illustrated in Fig. 27, and that has horizontal belts of transparent filters according to the third embodiment of the arrangements according to the invention,
- 20 Fig. 29 and Fig. 30 shows examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 27 and Fig. 28,
- Fig. 31 shows yet another example of the image combination,
- Fig. 32 shows a filter array that is excellently suitable for spatial display in conjunction with the image combination rule illustrated in Fig. 31, and that has vertical belts of transparent filters according to the third embodiment of the arrangements according to the invention,
- 30 Fig. 33 and Fig. 34 shows examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 31 and Fig. 32,
- 35

[CERTIFIED TRANSLATION FROM GERMAN]

- 11 -

- Fig. 35 shows yet another filter array that may satisfy the requirements of the first and second embodiments of the invention, comprising R', G', B' filters and gray level filters,
- Fig. 36 shows yet another possible embodiment of a filter array,
- 5 Fig. 37 schematically illustrates the composition of transparent filter segments from transparent filter elements as used in Fig. 36,
- Fig. 38 shows details of the filter elements used in Fig. 37,
- Fig. 39 and Fig. 40 show examples of pixels or partial areas of pixels possibly visible to one and the other of the observer's two eyes, respectively, based on the conditions shown in Fig. 36,
- 10 Fig. 41 shows another example with an image combination compiled from six views,
- Fig. 42 shows a filter array for use with the image combination shown in Fig. 41, and
- 15 Fig. 43 and Fig. 44 show examples of pixels or partial areas of pixels possibly visible to one and the other of the observer's two eyes, respectively, based on the conditions shown in Fig. 41.

20 **Detailed Description of the Drawings**

The drawings are not to scale; they may be greater or smaller than natural size. Some of the drawings are schematic illustrations of the principle, and some others show segments of the respective object only.

- 25 Fig. 1a shows a segment of a filter array in a first embodiment of the arrangement according to the invention. The filter array is composed of a great number of wavelength filters. The filters or filter elements provided here are only such that are either essentially transparent or opaque to the visible spectral range. As shown in Fig. 1b, the transparent filter segments of the filter array known from Fig. 1a are
- 30 composed of several transparent filter elements. In Fig. 1b, the dimensions of the (smallest) transparent filter elements are approximately 0.0997151 mm wide by 0.2991453 mm high, if the raster of pixels used is a 15.1" LC display of the LG type with a resolution of 1024x768 pixels at a full-color pixel size of 0.3 mm x 0.3 mm. The dimensions of the assembled transparent filter segments, shown in Fig. 1a, are
- 35 thus given inherently. The filter array extends approximately over the same area as the active image area of an LC display, or of the imaging device in general.

- 11 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 12 -

Reference is made below to Fig. 1c, in which schematically indicated observer eyes 3 look at a filter array 2. If the filter array 2 is arranged, as shown in Fig. 1c, in front of a raster 1 of rows j and columns i of pixels α_{ij} , the arrangement according to the invention is implemented in an embodiment in which the quotient of the sum of areas of the filter elements β_{pq} that are largely transparent to light of essentially the entire visible spectrum and the sum of areas of all filter elements β_{pq} of the respective array has a value that is between the quotient $Q1=1.1/n'$ and the quotient $Q2=1.8/n'$, so that, due to the filter elements β_{pq} transmissive to light of the entire visible spectrum, always about 1.1 to 1.8 pixels α_{ij} are visible, on average, per visible segment of the raster relative to the pixel area. The filter elements transmissive to light of specified wavelength ranges are designed as transparent filters.

With regard to this, an image assembled from four views according to the image combination rule illustrated in Fig. 2 is used on the raster of pixels. Here and in further drawings, the columns R, G, B denote red, green and blue subpixel columns (or also subpixel rows). Thus, in this case, the average number of different views n' displayed on the pixels α_{ij} per row i of the raster is $n' = 4$.

If, for example, according to Fig. 1b, one selects a 12x12 field of the smallest filter elements whose raster is discernible here, it is evident that, on the (one) array provided, the quotient of the sum of areas covered by filter elements β_{pq} largely transparent to light of essentially the entire visible spectral range and the sum of the areas covered by all filter elements β_{pq} is $48/144 = 1/3$. With $n' = 4$, the said quotient $1/3$ satisfies the requirement of lying between the quotient $Q1 = 1.1/n' = 0.275$ and the quotient $Q2 = 1.8/n' = 0.45$.

Fig. 3 and Fig. 4 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 1a and Fig. 2. From these it is evident that, because of the filter elements β_{pq} that are transmissive to the complete visible spectrum, i.e. the transparent filters, always about 1.1 to 1.8 pixels α_{ij} , on average, are visible per visible raster segment with reference to the pixel area, or, more precisely, about 1.33 pixels α_{ij} in this case. For example, a visible share of about one third of the area of the pixel adjacent on the right borders on the top left pixel visible at the location (1,1) in Fig. 3.

35

[CERTIFIED TRANSLATION FROM GERMAN]

- 13 -

Because of the visibility conditions prevailing here (see Fig. 3), an observer sees, e.g., a selection comprising the views A_k with $k = 1, 2, 3$, in which the visible area shares relate as 3:8:1. The observer's other eye, the visibility conditions of which are exemplified in Fig. 4, would see, e.g., a selection comprising the views A_k with $k = 3, 4, 1$, in which the visible area shares also relate as 3:8:1.

It may be noted here that, because of the visibility conditions of the arrangements according to the invention, the readability of 2D text relative to 3D arrangements and methods known in prior art is further improved.

10

Fig. 5 shows another example of the image combination, which is particularly suitable for a display intended for mobile use, such as that of a PDA (Personal Digital Assistant) or a mobile phone. Fig. 6 illustrates a filter array that is, in conjunction with the image combination rule illustrated in Fig. 5, excellently suitable for three-dimensional display, and that allows the implementation of an embodiment in which, in case of the parallel projection of a sufficiently large filter segment of at least one array of filter elements β_{pq} onto at least one row j or at least one column i of the raster, at least $1.1/n'$ times, but at most $1.8/n'$ times the area of the respective row j or column i is covered by filter elements β_{pq} essentially transmissive to light of the complete visible spectrum, so that, because of these transmissive filter elements β_{pq} , always about 1.1 to 1.8 pixels α_{ij} are visible, on average, per visible raster segment with reference to the pixel area. The filter elements transmissive to light of specified ranges are also designed as transparent filters.

Here again, with reference to Fig. 5, the average number of different views displayed on the pixels α_{ij} per row i of the raster is $n' = 4$.

Whereas Fig. 7 and Fig. 8 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 5 and Fig. 6 or with reference to a relative arrangement as shown in Fig. 1c, the first-named drawings also serve to illustrate the properties required.

In so far as the distance z between the filter array and the raster of pixels is not too great, i.e. about less than one percent referred to the selected viewing distance d_s of the observer's eyes 3, the drawings Fig. 7 and Fig. 8 approximately illustrate quasi-parallel projections of the filter array onto the raster of pixels α_{ij} .

[CERTIFIED TRANSLATION FROM GERMAN]

- 14 -

If one regards, in Fig. 7 or Fig. 8, these (quasi-)parallel projections of the respective filter segment shown (which is assumed to be sufficiently large) of the array of filter elements onto column $i = 1$ of the raster of pixels α_{ij} , it is evident that about one
5 third of the area of column i is covered by transparent filters. This satisfies the requirement that at least $1.1/n'$ times and at most $1.8/n'$ times the area of the respective column i is covered by transparent filters, as $1.1/4 < 1/3 < 1.8/4$.

Accordingly, because of the said transparent filter elements β_{pq} , always about 1.1 to
10 1.8 – or, in this case, precisely 1.33 – pixels α_{ij} are visible, on average, per visible raster segment with reference to the pixel area.

Analogously, this could be shown for the rows.

15 As a peculiarity of the image combination illustrated in Fig. 5 it should be noted that it features RGB color subpixel rows rather than RGB color subpixel columns as in many LCD screens. An image constructed in that way is provided, for example, in a PDA (Personal Digital Assistant) of the make Compaq iPAQ 3600 Pocket PC; this PDA make is excellently suitable for 3D display in conjunction with the applications
20 outlined before. Here, the filter dimensions are, for example, 0.319607 mm wide x 0.079922 mm high, corresponding to the broken-line rectangle in Fig. 6.

In the sense of the embodiment just described, Fig. 9 shows another example of the image combination, and Fig. 10 shows a filter array that is excellently suitable for
25 three-dimensional displays in conjunction with the image combination rule illustrated in Fig. 9. here again, the characteristic requirements for the arrangement according to the invention are satisfied, which can easily be proved. The raster of pixels α_{ij} used here is, for example, a plasma display of the make Pioneer PDP 503 MXE. Here, the filter dimensions are, e.g., 0.379646 mm wide x 0.80442478 mm
30 high, corresponding to the broken-line rectangle in Fig. 10.

Finally, Fig. 11 and Fig. 12 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 9 and Fig. 10.

35

[CERTIFIED TRANSLATION FROM GERMAN]

- 15 -

Yet another example of a filter array in the sense of the invention is shown in Fig. 13a. Preferably, this filter array should be used with an image combination rule according to Fig. 9. For easier understanding, Fig. 13b schematically illustrates the composition of transparent filter segments from several transparent filters or filter elements. The filter array shown in Fig. 13b is equivalent to that shown in Fig. 13a. In this respect, Fig. 14 is an example of the pixels or partial areas of pixels visible to one eye of the observer, based on the conditions shown in Fig. 9 and Fig. 13a.

Incidentally, the filter array illustrated in Fig. 13a or Fig. 13b implements the case that, on at least one of the arrays of filter elements provided, in at least one row q of the array, immediately neighbored transparent filters border on a different number of immediately neighboring transparent filters on row $q-1$ than on row $q+1$. For example, in row $q = 8$ in Fig. 13b it is evident that the immediately neighboring four transparent filters shown border on four immediately neighboring transparent filters of row $q+1 = 9$, whereas they border on only one of the four immediately neighboring transparent filters of row $q-1=7$.

Fig. 15 shows another example of a filter array in the sense of the invention. Preferably, this filter array should also be used with an image combination rule according to Fig. 9.

Fig. 16 shows an example of the pixels or partial areas of pixels visible to one eye of the observer, based on the conditions shown in Fig. 9 and Fig. 15.

Incidentally, the filter array illustrated in Fig. 15 also implements the case that, on at least one of the arrays of wavelength or gray level filters provided, in at least one row q of the array, immediately neighbored transparent filters border on a different number of immediately neighboring transparent filters on row $q-1$ than on row $q+1$.

Fig. 17 shows a filter array in another embodiment of the invention, preferably to be applied with an image combination rule according to Fig. 9, whereas Fig. 18 shows an example of pixels or partial areas of pixels possibly visible to one eye of the observer, based on the conditions shown in Fig. 9 and Fig. 17.

Fig. 19 shows yet another example of the image combination, and Fig. 20 illustrates a filter array according to the invention that is excellently suitable for three-

- 15 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 16 -

dimensional displays in conjunction with the image combination rule according to Fig. 19. Fig. 21 and Fig. 22 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Fig. 19 and Fig. 20. Here, eight views are presented, each of which is displayed in each row. As
5 an alternative, one could present, e.g., 40 views instead, with preferably only eight different views (e.g., 1, 6, 11, 16, 21, 26, 31, 36) being displayed per row. Thus, the number of views n' displayed per row as described above would also be $n' = 8$.

Yet another example of an embodiment of the invention is shown in Figs. 23
10 through 26.

Of that example, Fig. 23 shows the image combination, Fig. 24 a filter array that is excellently suitable for three-dimensional displays in conjunction with the image combination rule according to Fig. 23, and Figs. 25 and 26 illustrate examples of
15 pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the conditions shown in Figs. 23 and 24. Here again, eight views are used for spatial presentation.

The further drawings illustrate in detail a third version of the arrangements according to the invention, in which at least one first continuous belt of transparent filters extending from one edge of the array to the opposite edge and at least one second continuous belt of transparent filters extending from one edge of the array to the opposite edge are provided, with the major extensions of these two belts on the array are not aligned in parallel with each other.

25 For this embodiment of the arrangement according to the invention, Fig. 27 shows another example of the image combination, and Fig. 28 a matching filter array with horizontal belts of transparent filters. Fig. 29 and Fig. 30 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes, based on the
30 conditions shown in Fig. 27 and Fig. 28.

As can be seen from Fig. 28, examples of horizontal belts of transparent filters are provided. Also provided are stepped, oblique belts extending from the lower to the upper edge of the filter array, so that the main directions of light propagation of the
35 horizontal and oblique belts are not parallel with each other. In practice, the filter array comprises many more filter elements; for the sake of clarity, the figure shows

- 16 -

[CERTIFIED TRANSLATION FROM GERMAN]

- 17 -

only a random segment of the filter array. Advantageously, a great number of such continuous belts of transparent filters are provided. As shown in Fig. 28, it is advantageous to space some or all of the continuous, horizontal belts of transparent filters at periodic distances on the array. here, for example, every fourth row q (i.e. with $m = 4$) of the array forms such a continuous horizontal belt of transparent filters.

As Fig. 29 shows for this example, in case of parallel projection of any, but not necessarily each, continuous horizontal belt of transparent filters onto the raster of pixels α_{ij} in viewing direction, predominantly such pixels α_{ij} are, at least partially, covered by transparent filters that in this case exclusively render bits of partial information of one and the same view A_k .

Another example of how the abovementioned embodiment of the arrangements according to the invention can be configured is given below. Fig. 31 shows the image combination for this example, Fig. 32 an excellently suitable filter array featuring vertical belts of transparent filters, among others, and Fig. 33 and Fig. 34 show examples of pixels or partial areas of pixels possibly visible to an observer's two eyes.

As can be seen in Fig. 32, the filter array is provided with both oblique and vertical continuous belts of transparent filters. As shown for this example in Fig. 33, in case of parallel projection of any, but not necessarily each, continuous vertical belt of transparent filters onto the raster of pixels α_{ij} in viewing direction, predominantly such pixels α_{ij} are, at least partially, covered by transparent filters that in this case predominantly render bits of partial information of one and the same view A_k with $k = 5$.

Fig. 34 would approximately correspond to a slightly displaced oblique view, i.e. not to the parallel projection in viewing direction (which, in strict terms, would lie in a direction parallel to the midperpendicular to the raster of pixels), but rather to a parallel projection in an oblique direction.

Contrary to the embodiments outlined before, it is also feasible to design the image combination rule in such a way that, in case of parallel projection of any, but not necessarily each, continuous belt of transparent filters onto the raster of pixels α_{ij} in

[CERTIFIED TRANSLATION FROM GERMAN]

- 18 -

viewing direction, several of such pixels α_{ij} are, at least partially, covered by transparent filters that render bits of partial information of at least two different views A_k . Various variations of the respective (at least two) views A_k are feasible: For example, more than the required minimum of two views can be used, e.g., n or $n-1$ views. Also, the image combination structure for pixels covered at least partially by transparent filters in case of parallel projection as described above, may be a random structure – rather than a periodic one as described before, e.g., in Fig. 9 – of bits of partial image information from several views. It is decisive for creating a 3D impression that the observer's two eyes see different selections of views, i.e. view mixes.

Moreover, in the above embodiments of the arrangements according to the invention, the width of the belts of transparent filters may vary. In case of the "oblique" belts described above, in particular, the width of the transparent filter segments per row may be selected to make the quotient of the total area of the transparent filters on the array and the total area of all filter elements on the array smaller than $1.1/n'$ or greater than $1.8/n'$.

Fig. 35 shows another filter array that may satisfy the requirements of the embodiments of the invention described first above, and that is supplemented by R' , G' and B' filters as well as gray level filters, with R' denoting red, G' green and B' blue wavelength filters. The respective filter elements cover the outlined parts of the area only. $L2$ denotes neutral, gray level filters that attenuate the light intensity by 50%, irrespective of the wavelength. These, as well as the R' , G' or B' filters, are left out of consideration if, as regards the characteristic features according to the invention, such filter elements are referred to that are largely or essentially transmissive to light of essentially the entire visible spectral range. As the R' , G' and B' filters are transmissive only to their respective red, green or blue wavelength ranges, and as the $L2$ filters attenuate the light intensity in no insubstantial degree, there is no speaking of „largely“ or „essentially transmissive“ here.

Another embodiment of a filter array according to the embodiments described first above is shown in Fig. 36. Unlike in the examples described above, in which the surfaces of the filter elements β_{pq} facing the front, i.e. the observer, have the form of regular rectangles, in this case filter elements β_{pq} of many different shapes are used, so that the oblique stripes covered, e.g., with transparent filters, get essentially smooth edges. This can be made clear by means of Figs. 37 and 38. Fig. 37

[CERTIFIED TRANSLATION FROM GERMAN]

- 19 -

shows, as a grid structure, the array on which the filter elements β_{pq} are arranged. The individual filter elements used are shown side by side in Fig. 38. The correlation to, or combination into, a mask image can be determined analogously with the equation for b described above; however, every value of b now relates to one of the shapes shown in Fig. 38. Fig. 39 and Fig. 40 show examples respectively for the left and the right eye 3 of the observer, i.e. the figures show which pixels with which views are seen by the two eyes from a given observer position. Moreover, it is also possible to arrange the stripes vertically instead of obliquely. In this example, too, as well as in the following one, the quotient of the sum of areas covered by filter elements β_{pq} largely transmissive to light of essentially the entire visible spectral range and the sum of the areas covered by all filter elements β_{pq} is between 1.1 and 1.8.

A last example of an embodiment following those described first above is illustrated by Figs. 41 through 44. Fig. 41 shows an image combination of six views ($n' = 6$); combinations of more or fewer views are also possible, though. Fig. 42 shows a filter array that is excellently suitable for three-dimensional displays in conjunction with the image combination rule according to Fig. 41. Fig. 43 and Fig. 44 show, by way of example, which pixels with which views are seen by the two eyes of an observer from a given position.

In Fig. 42, the dimensions of a transparent filter are indicated by broken lines. The width of the transparent filter approximately equals that of a pixel α_{ij} ; for example, it may be exactly 99.86% of the pixel width. The height of the transparent filter is about 1.5 times or, for example, exactly 149.8% of the height of a pixel α_{ij} . These conditions prevail, e.g., with some 18.1-inch LC displays, where the mean width of the pixels is 0.28047 mm and the mean height is 0.09349 mm. A transparent filter element, then, is about 0.420146 mm high and 0.093366 mm wide.

If the individual transparent filters of the filter array have only half the height compared to that shown in Fig. 42, it is possible to implement the structure via the determination of the mask image according to the above equation.

Compared to prior art, the invention has the advantage that it permits the image brightness in 3D display to be increased. In conjunction with this, it ensures improved text readability on the arrangements according to the invention.